Lean Aerospace Initiative
Product Development & Supplier Relations Focus Teams

Causes and Impacts of Engineering Changes

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Presented By:
Ted Hsu

Research Sponsored by the Lean Aerospace Initiative

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Presentation Outline

- **Motivation**
- **Key questions**
- **Research design**
- **Findings**

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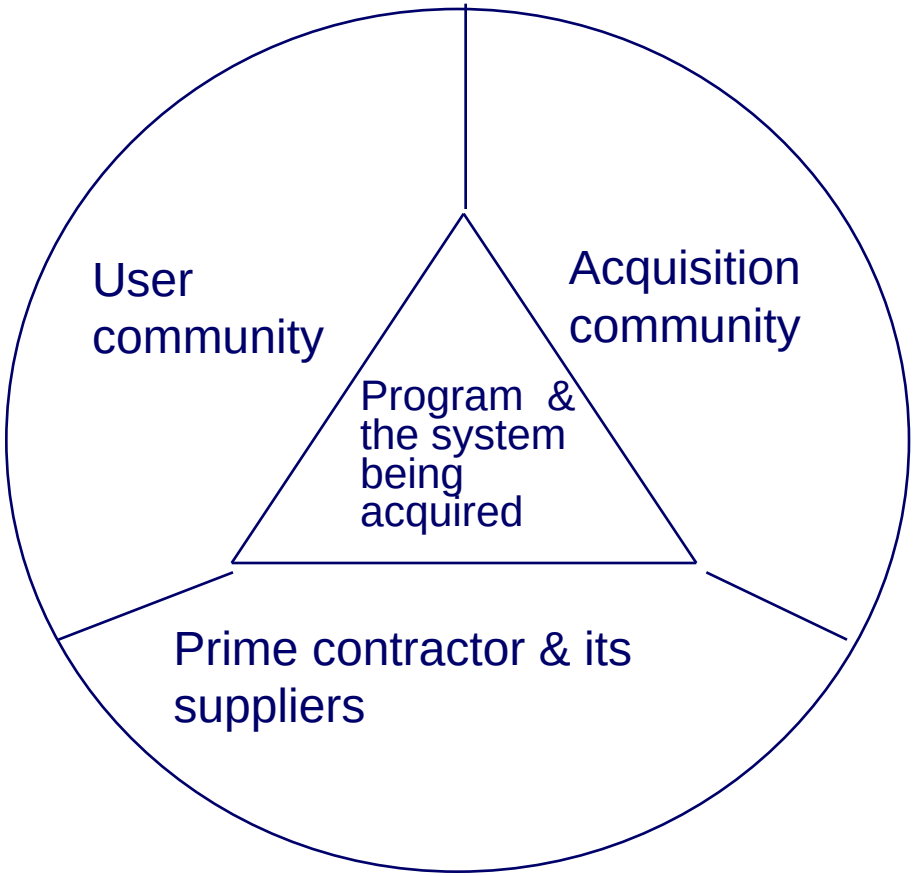
Motivation

- **Goal: Guidelines for reducing defense aerospace product cost & development cycle time**
- **Literature: Engineering Changes lead to increased cost & cycle time**
  - How do these results apply in defense aerospace product development?
- **Context: Defense aerospace**
  - Different communities



Note: Diagram adopted from Ellis & Ludwig's *Systems Philosophy*, & Blanchard's *System Engineering Management.*

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Class I Engineering Changes: Development & Production Phases

- **Impacts on product form, fit, or function**
- **Functionalities or physical config different before/after engineering change**
- **Visible to all communities**
- **Significant effort to process an engineering change**

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Key Questions

- **What are the major causes and impacts of engineering changes?**
- **What are practices that would help reduce undesirable engineering changes?**
- **What might the customer do to help reduce undesirable engineering changes?**

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Research Design

- **Method**
  - Case studies focusing on 3 major defense aerospace programs
- **Database**
  - Studied 118 engineering changes
    - Engineering Change Proposal (ECP) contractor submittals
    - Program A: 60, Program B: 31, Program C: 27
    - Each set comprehensive for each program until 11/17/1997
    - Supporting documents & written background information
  - Conducted formal & informal interviews
    - Personnel interviewed
      - Government (24)
      - Contractors (29)
    - Purpose of interviews
      - Obtain perspectives on programs & engineering changes

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Overview of Case Studies

- **Program A - Major aircraft subsystems upgrade**
  - Modification program to integrate 4 electronics mission subsystems
  - Single prime contractor
  - No IPTs during development
- **Program B - Major electronics subsystem upgrade**
  - Modification program - technology upgrade
  - Somewhat dependent on Program A
  - Two primes during development, customer as integrator
  - No IPTs during development
- **Program C - Major aircraft development & production program**
  - New program, single prime contractor
  - Integrate Program A basic electronics mission subsystems into aircraft
  - Incorporate some newer technology
  - IPTs during development

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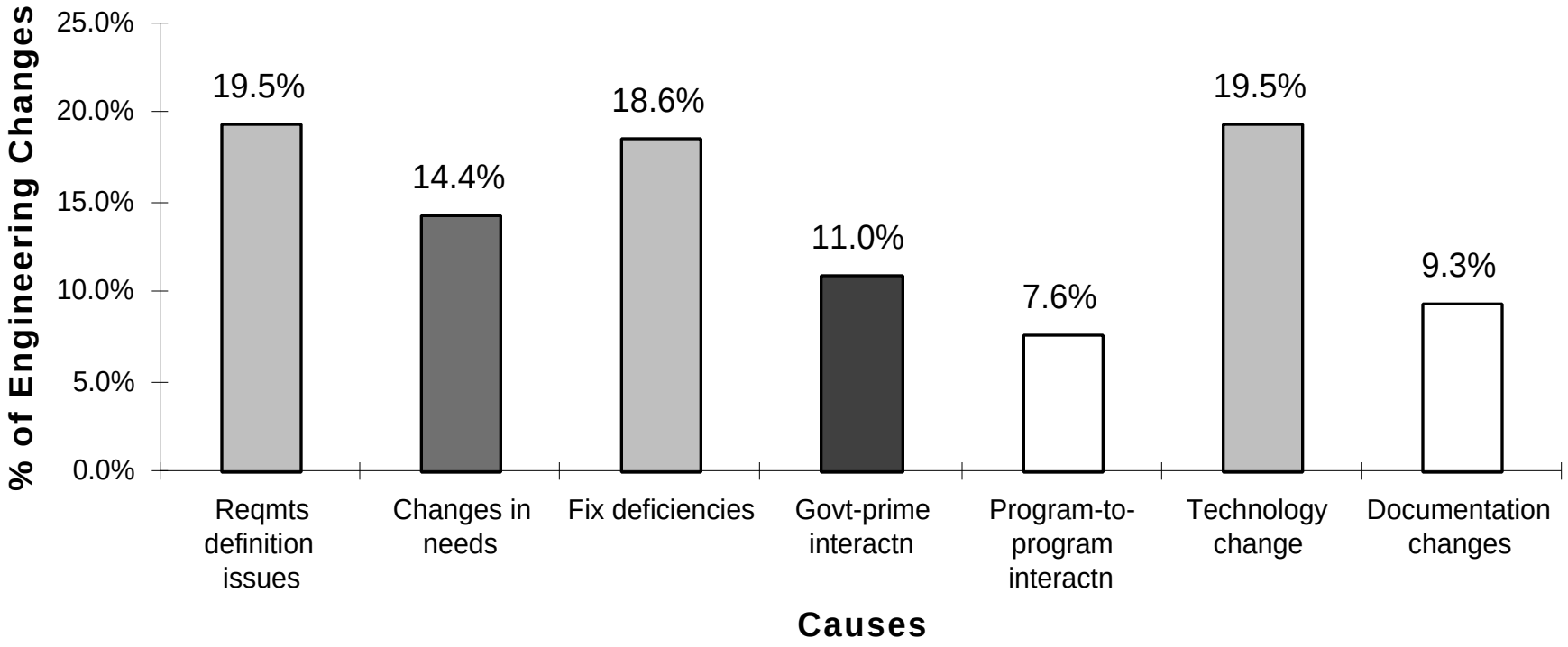
Primary Causes of Engineering Changes

Across 3 programs, based on all engineering change data (118)



- **Comprehensive data set identified 3 dominant causes**
- **Added two more based on data normalizations**

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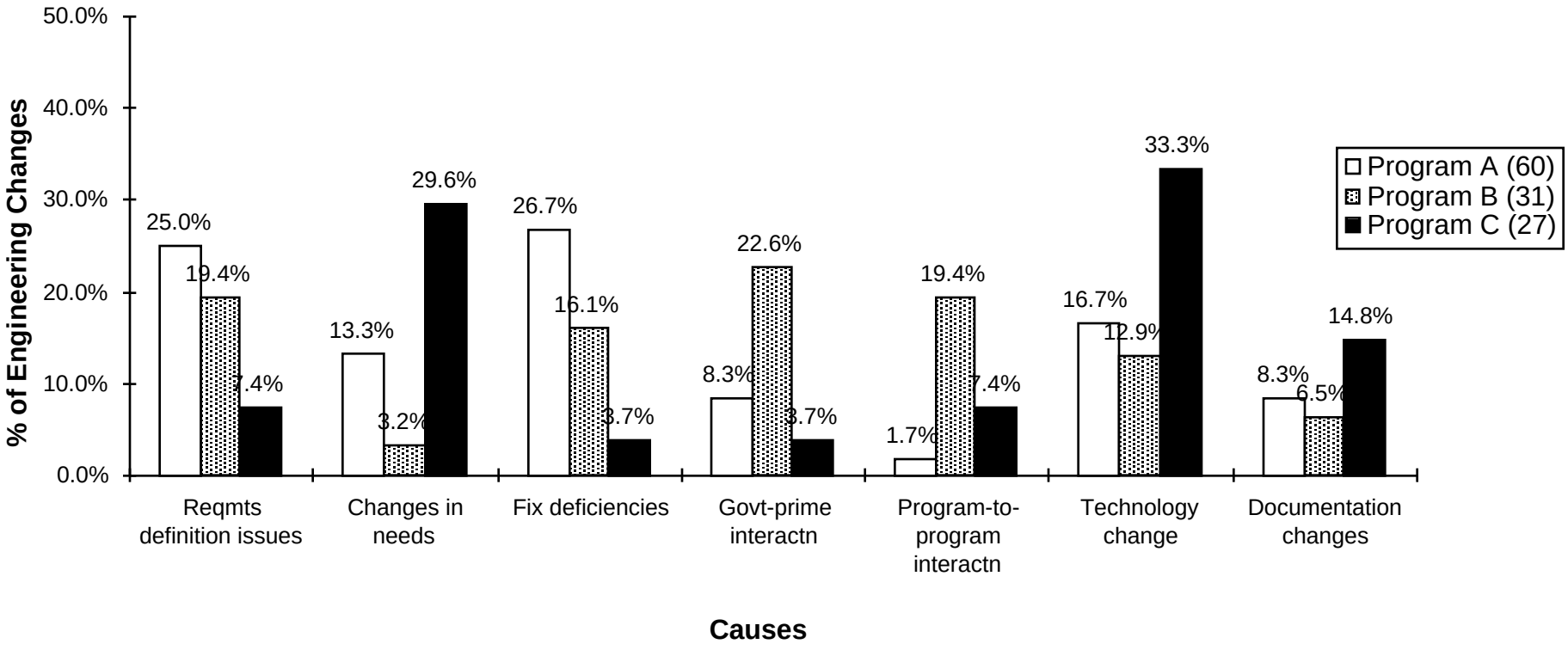
Program Comparison: Primary Causes of Engineering Changes

Across 3 programs, based on all engineering change data (118)



- **Combinations of dominant causes are different across programs**
- **Conventional wisdom would predict major program schedule delay in Program C. Is the prediction correct?**

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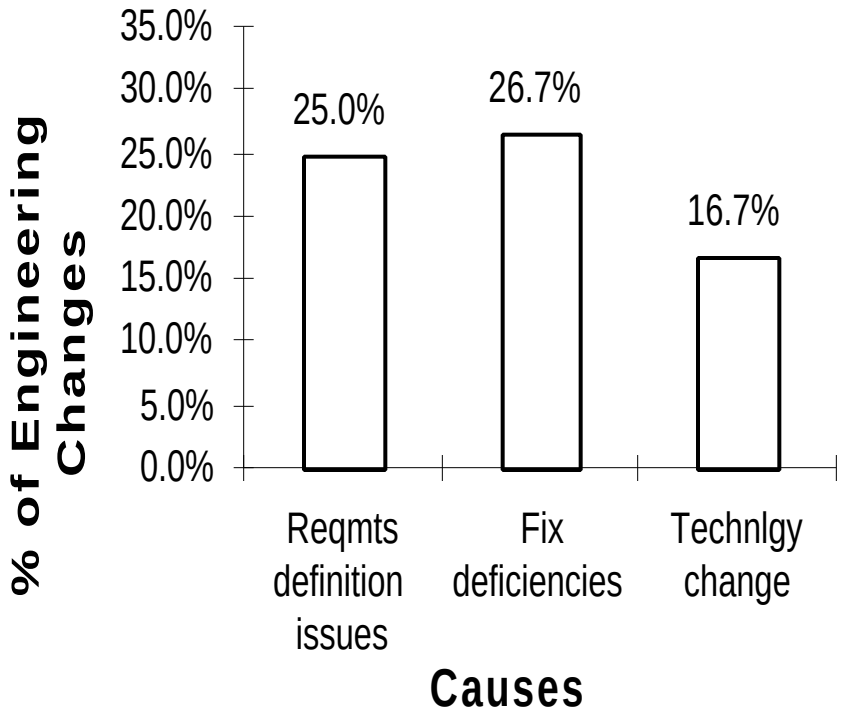
Program A Dominant Causes



Total Program A engineering changes: 60

Program Key Characteristics

- Dominated by complex, modified OTS system integration
- Supplier of OTS system involved in development early
- Many redesigns on OTS system
- Recent producibility & reliability problems
- Other mission systems evolved by introducing newer technology

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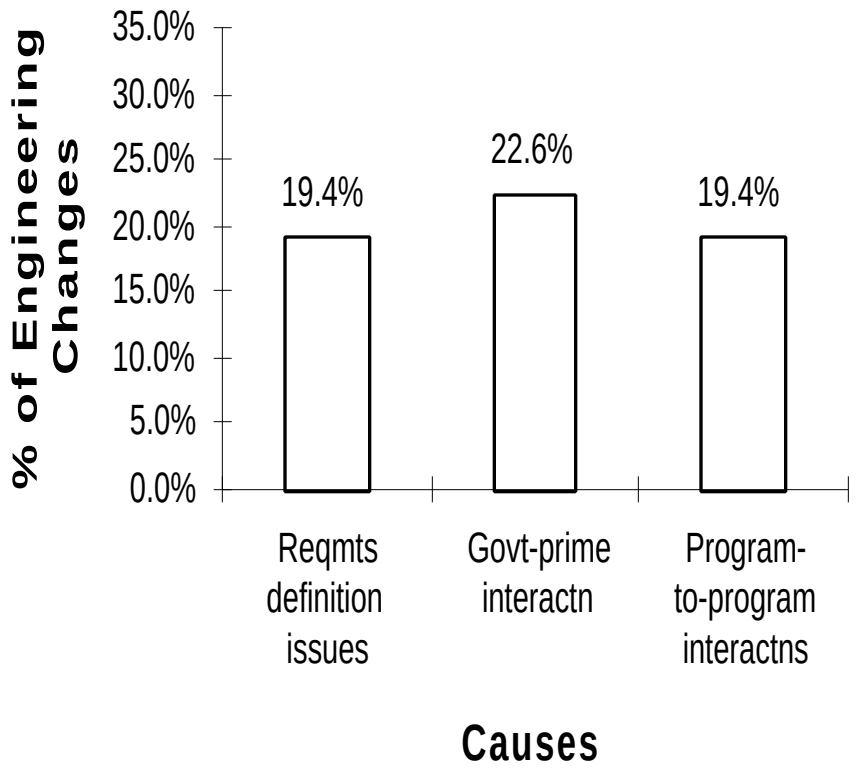
Program B Dominant Causes



Program Key Characteristics

- Subsystems suppliers involved early in design
- Two primes during development
  - Reqmts-related questions remained despite frequent contacts
  - 2 engineering changes per ECP issue
- Program baseline shifted due to changes in Program A

Total Program B engineering changes: 31

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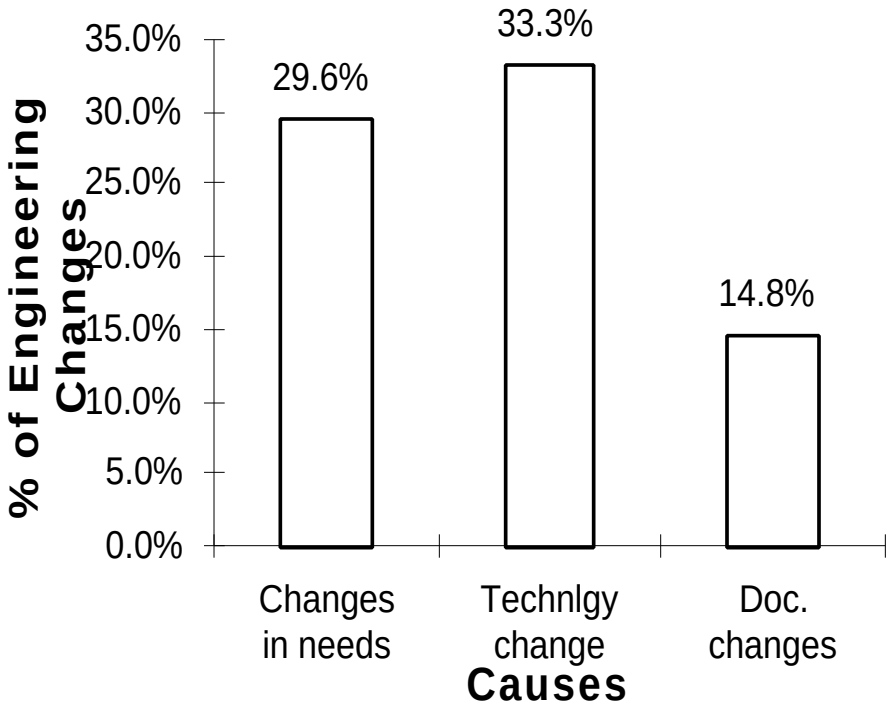
Program C Dominant Causes



Program Key Characteristics

- Program schedule a priority
- Clarified reqmts early
- Opportunities for fast customer learning
  - Accommodate newly definitized needs
  - Add newer, low risk technology
- Documentation changes mostly due to program newness

Total Program C engineering changes: 27

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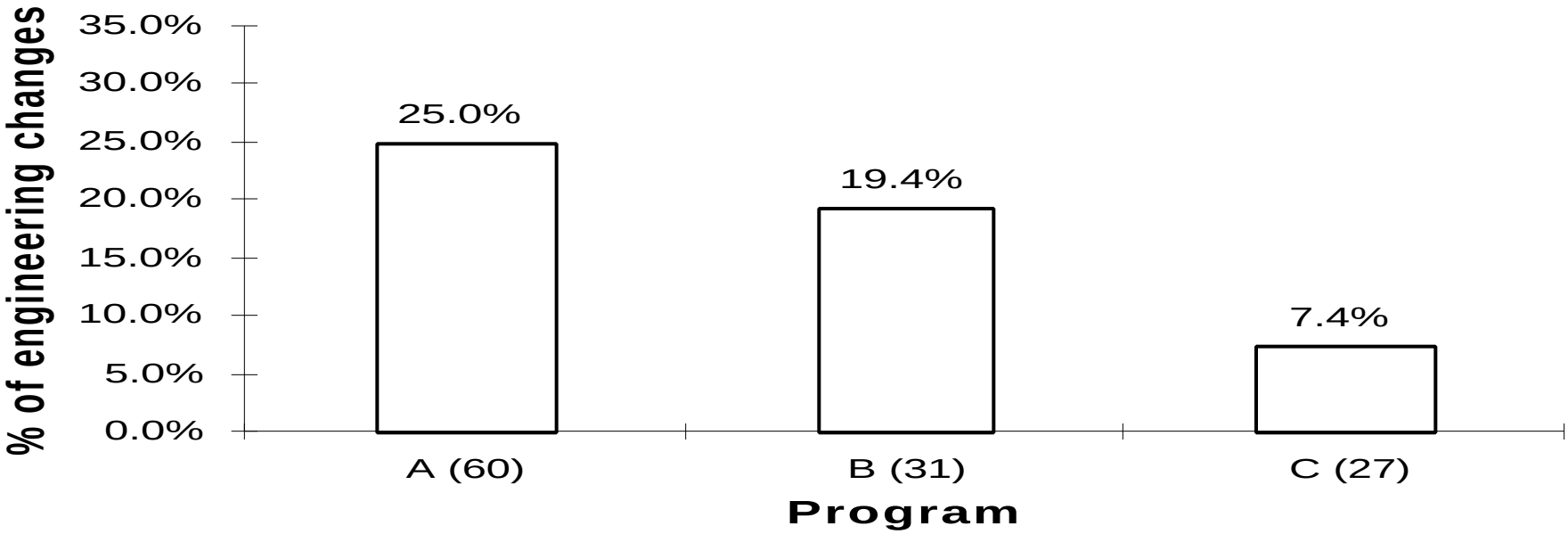
Requirements Definition Issues



Use of IPTs helped clarify design assumptions/capabilities as much as possible early in Program C, thereby reducing engineering changes due to "Requirements definition issues".

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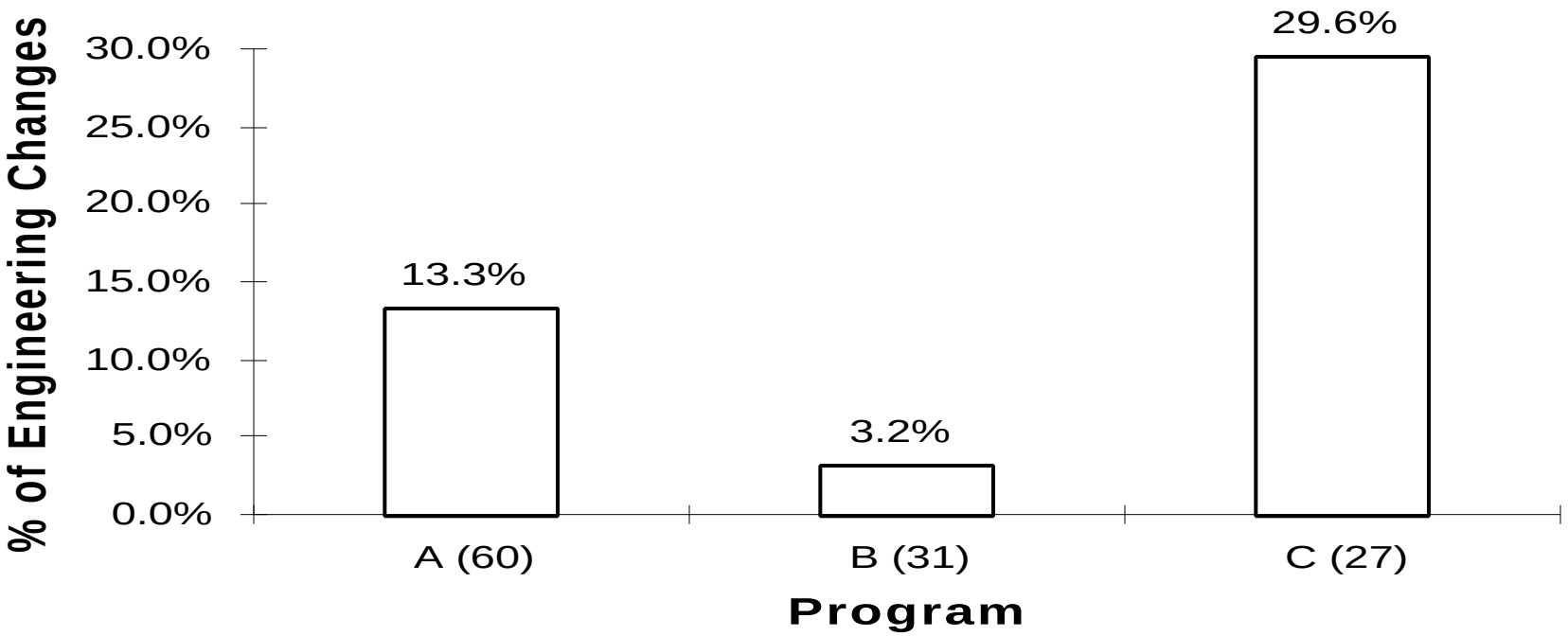
Changes in Needs



Due to few "Reqmts definition issues", Program C quickly accommodated evolving customer needs as customer learned more about its needs.

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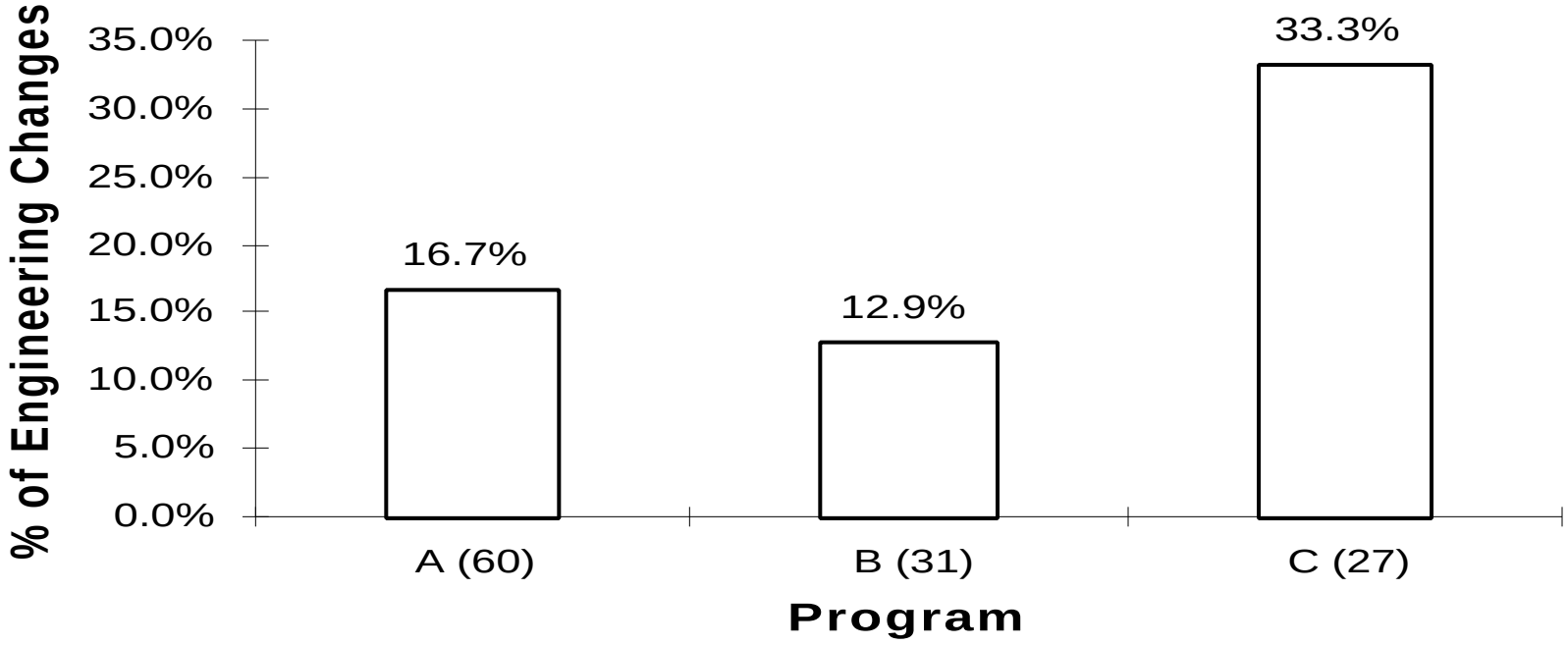
Technology Advances



- **Program C also had opportunity to quickly incorporate newer technology**
- **The newer technology involved tended to be low risk**

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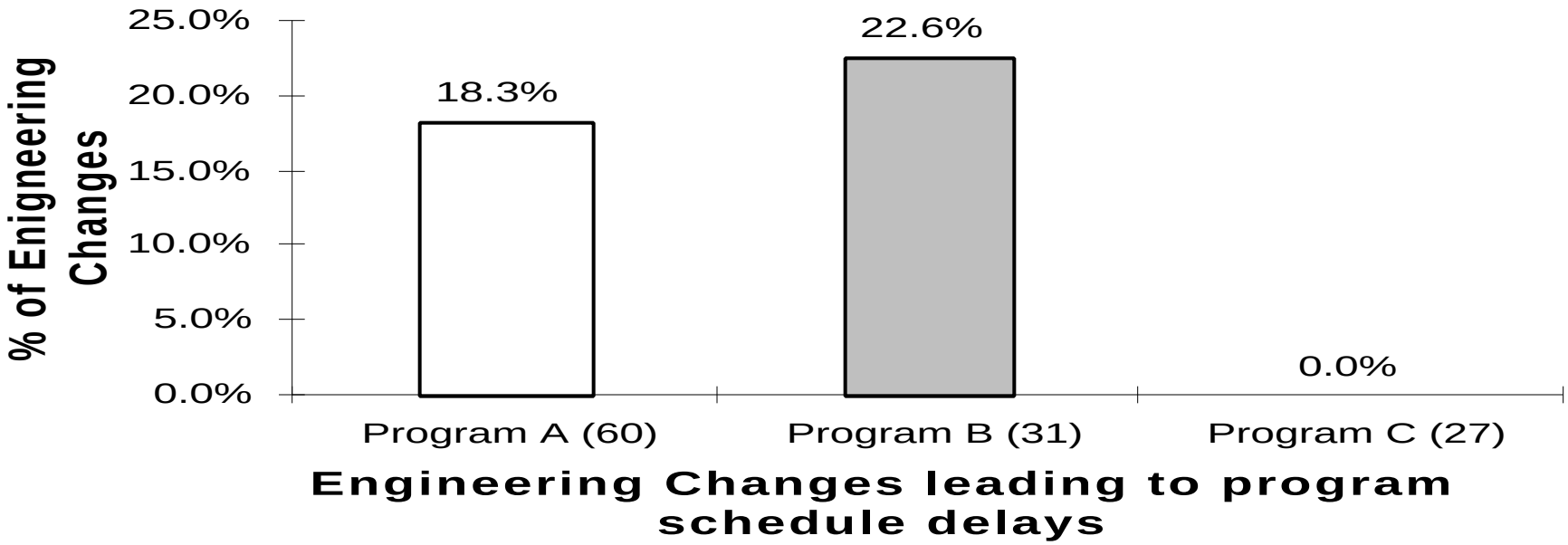
Impacts of Engineering Changes on Program Schedule



- **Program C schedule priority ensured no program schedule delay**
- **Programs A & B engrg change-related schedule delays due primarily to "Reqmts definition issues" & "Fix deficiencies"**
- **Not all program schedule delays are due to engrg changes: other mechanisms exist to allow schedule delay**

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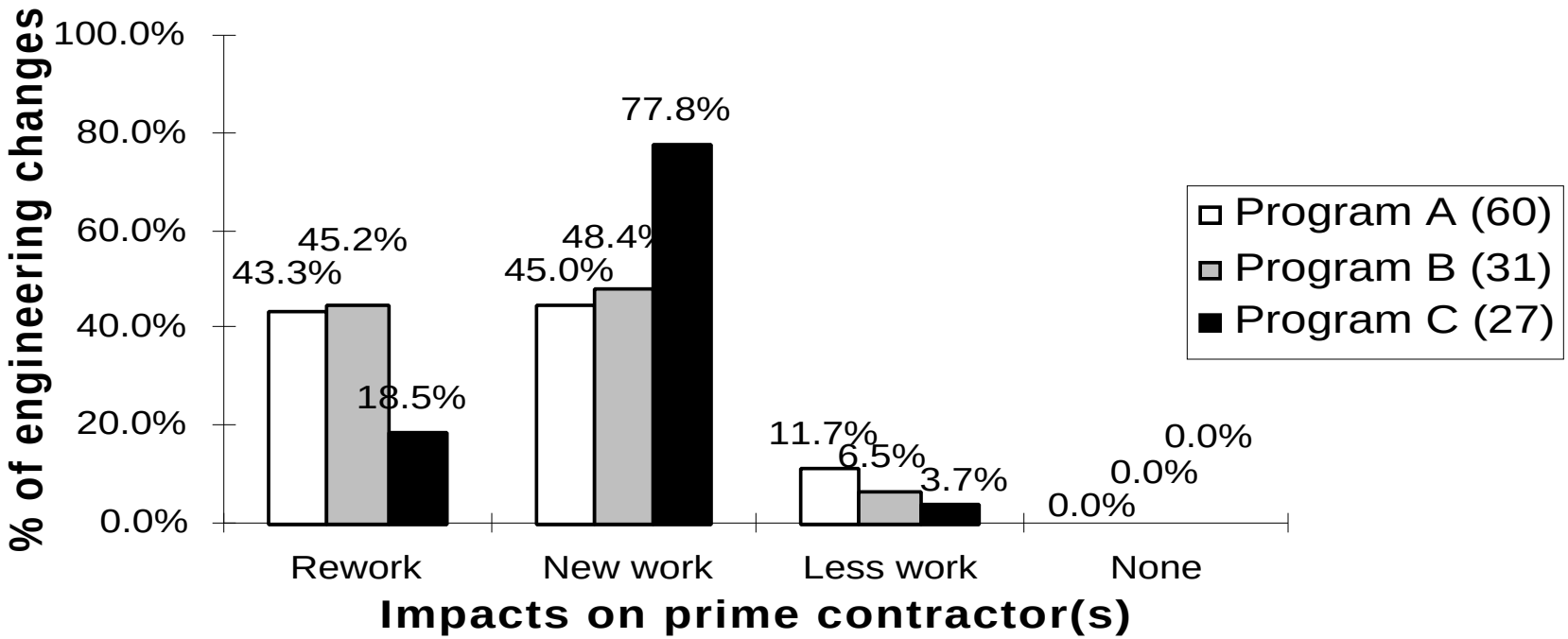
Impacts of Engineering Changes on Prime Contractors



- **Use of IPT helped prime of Program C clarify reqmts early, & have less "Rework" than primes in Programs A & B**
- **Engineering changes infrequently provide relief from reqmts for primes**

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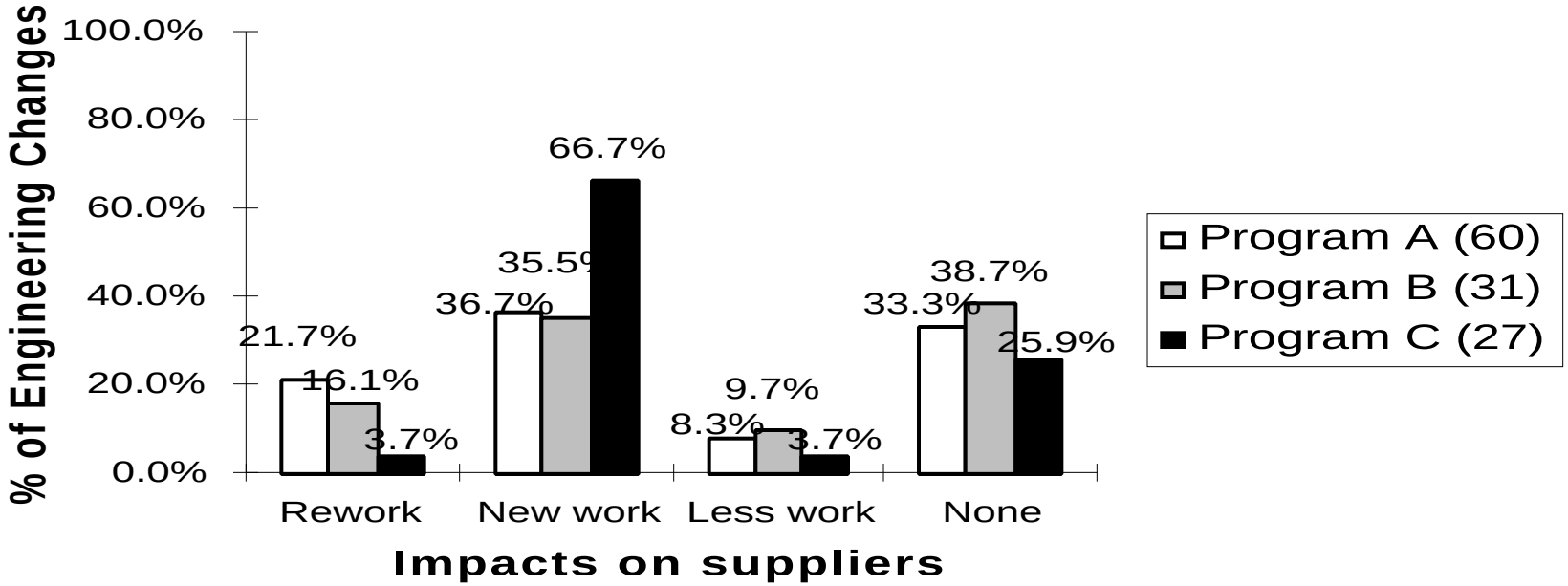
Impacts of Engineering Changes on Suppliers



- **Use of IPTs including key suppliers may have helped clarify key suppliers' capabilities to the primes early in Programs A & B, thereby avoiding some "Rework"**
- **Engineering changes infrequently provide relief from reqmts for suppliers**

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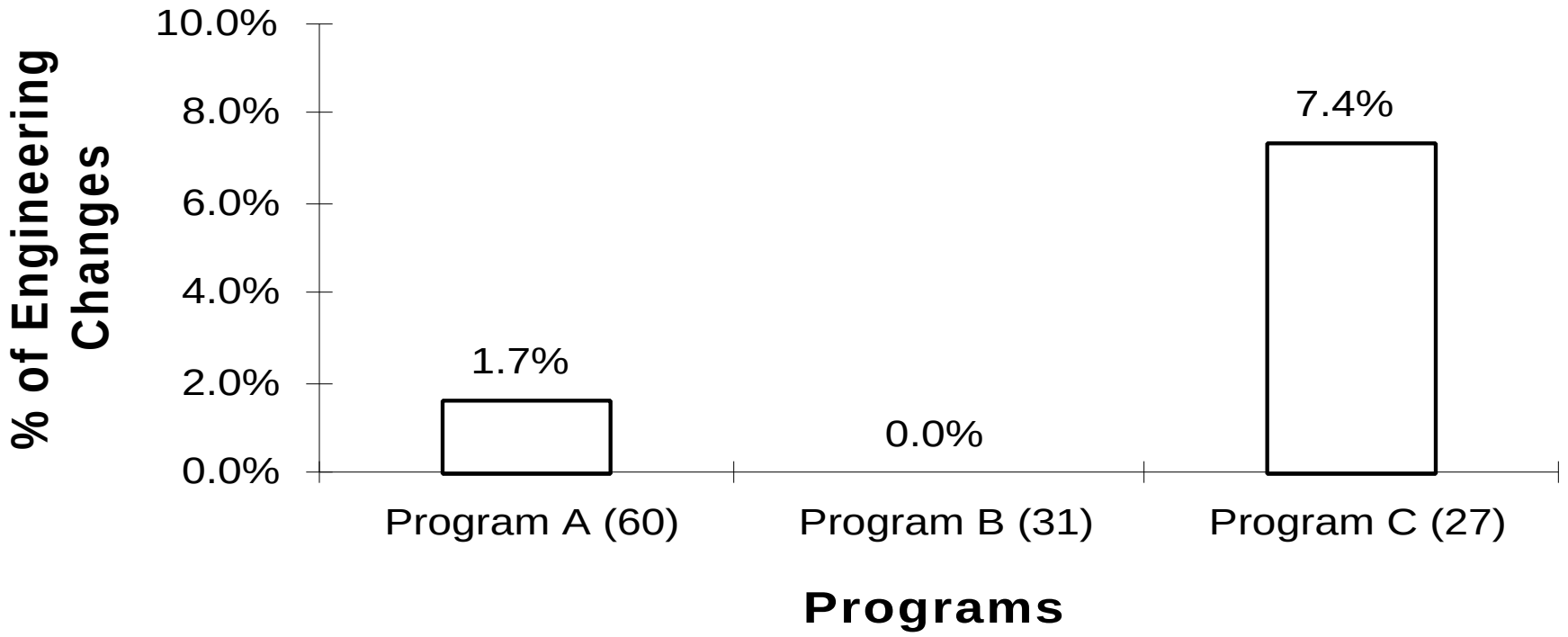
Engineering Changes Resulting in Unanticipated Engineering Changes



- **Majority of engrg changes do not result in surprises to be dealt with using additional engrg changes**
- **Impact of engineering changes well-understood on change-by-change basis.**

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Summary of Findings

- Five dominant causes of engineering changes identified
- Combination of dominant causes in each program driven by characteristics & practices in each program
- Use of IPTs enabled reduction of engineering changes due primarily to “Requirements definition issues”
- Lessons on supplier integration into product development
  - Early involvement not always sufficient to reduce undesirable engrg changes
  - Reduction of undesirable engrg changes requires understanding of key suppliers’ capabilities by primes, IPT environment would help
- Frequent changes in needs and insertion of newer technology can be done without PD cycle time increases
- Few engineering changes provide relief from requirements for primes & their suppliers
- Impacts of individual change well understood, a tribute to capabilities of all parties

